having then been caused through violent onsets of the gnats in the country not far south of Rayville, Richland parish. Even the Ouachita river, which courses southward in a line as far west as Monroe, La., was sweeping over its banks at the same time, but nothing could be learned that would implicate any outbreak of the pests in connection with the submergence of the marginal tracts of land. However, as Major Lee has referred to an experience with the foe in 1912, which is recounted in the fore part of this paper, the incident may have been occasioned by an event similar to the latter.

At Baton Rouge on March 13, 1915, Dr. W. H. Dalrymple told of an inquiry that had just come to his hand from a correspondent who gave his address as Lloyd, Rapides parish, La. The inquirer desired to be informed of the best treatments to use for protecting farm stock from onslaughts of black flies. He requested this information in order to take prompt action for saving his animals in case the pests should appear again like swarms of them had done at a corresponding time of the year before. Several head of animals in the parish were said to have succumbed to the fury of that invasion.

Examples that were thought to be the species commonly called turkey gnat incidently became noticeable in the lakeside district of Baton Rouge during the last week of April, 1917. A member of the University faculty on one occasion called attention to the effects of a bite which had been inflicted on the lower edge of his eye. The attack took place while he was walking through the campus. On the same grounds a few days later the writer himself happened to feel the sudden grip of an insect on his neck, but killed it with a quick slap by the hand before it could bite. It answered to the species as already mentioned.

Initial Advances in Research Work with Insects Infesting Stored Rice.

ELBERT S. TUCKER,
Louisiana Agricultural Experiment Station, Baton Rouge.

METHODS OF CONDUCTING BREEDING TESTS.

Research work with insects infesting stored rice and its by-products was undertaken by the writer at the beginning of 1912. The breeding of different species of the pests that were encountered in the course of the investigations was conducted under both collective and isolated methods of handling the specimens and material. In this manner, the stock furnished a reserve supply and afforded a check on the isolations.

MANAGEMENT OF COLLECTIVE BREEDING.

Preparatory arrangements for collective breeding were made by placing each accession of infested stock in a suitable receptacle, such as a jar, crock, or can, which, on having the mouth properly covered, served as a cage. The most satisfactory cover used on the utensil consisted of a piece of muslin cloth cut to the desired size, this being fastened over the orifice with a cord tied around the edge. On containers other than those of clear glass, a hole was cut out in the center

of the cover and a glass tumbler or wide-mouthed bottle was placed in an inverted position over the opening. The latter barrier was provided as a trap for the retention of adult insects when they attempted to leave their quarters. These provisions readily facilitated the carrying on of regular observations upon the behavior of the various pests and their parasites so far as the forms appeared in any product held within the chamber. From time to time, the relative abundance and approximate increase or decrease in numbers of a given species in similar or different sorts of stock could be noted almost at a glance.

BREEDING IN ISOLATION.

After some deliberation regarding the procedure by which the several kinds of insects could be successfully bred in isolation, the following measures were devised and employed as offering the best advantages in harmony with storage conditions. They allowed observations to be taken day by day on the developmental phases of any form, whether kept in dark or exposed to light. The perfect determination of life histories depended on the breeding of each species in all of the diverse classes of stock that happened to be found infested by the particular insect. An equalization of other factors was secured by uniform manipulation so far as it proved to be practical for obtaining adequate results.

In the selection of specimens, the adults were preferred for starting a series comprising a number of individuals in a test. When the sexes could not be readily distinguished a few mature forms of a kind were confined together. Otherwise, when possible, active or mated pairs were chosen for the initiative step.

Small tin boxes were utilized for installing some confinements. In most cases, however, the isolations were made in tubular glass vials measuring not less than four inches in length and three-fourths of an inch in diameter. Each vial was provided with a stopper of special construction, designed with the object of allowing atmospheric changes to take effect within the tube in accord with the weather, and at the same time preventing escape of the inclosed insects. These provisions required only a simple device consisting of a tight-fitting cork, through the middle of which a vent of three-eighths of an inch aperture had been punched, the opening then being covered with a disk of fine brass gauze that was attached securely over the inner face of the stopper by means of small pins. By making the insertions at equal distances apart on the rim, no more than four pins were needed for holding the disk tight to the plug. The gauze when properly affixed and trimmed evenly around the circumference protected the cork from being gnawed or burrowed. Such damage was frequently committed by cadelle beetles whenever any portion of the stopper happened to be exposed within the tube containing these insects.

In order to obtain darkened conditions consistent with the habits of secretive insects, the tubes in most instances were placed under cover in pasteboard boxes and tilted so that the contained material and living forms remained together in the bottom of each inclosed space. For comparative purposes, specimens were occasionally left in full reach of diffused sunlight.

OCCURRENCES OF PESTS.

INFESTATION OF ROUGH RICE.

With the first inspection of stocks kept in storage, a quantity of rough Honduras rice that had been held for about a year in a general warehouse in New Orleans, La., was found to have undergone considerable damage by insects. Owing to the cold weather at the time of this visit, which was made on January 17, 1912, most of the pests were encountered in the form of beetles that existed in a dormant state. They hung in scattered numbers among the loose fibers on the dusty sides of the bags containing the rice. When placed in the hand for a while the specimens soon showed signs of life by crawling slowly, being revived by the warmth. The observations concerning the relative abundance and situations in which each kind presented itself are best mentioned in the following order:

The lesser grain borer, *Rhizopertha dominica* Fab. This insect was the prevailing species, most of the beetles being alive but dormant. It occurred most numerously on the outer sides of the tiers of bagged rice, but was also found among the grains.

The rust-red flour beetle, *Tribolium navale* Fab. The beetles of this species were associated with the former, being in a similar dormant condition, but occurring in much less numbers. They were taken mainly on the outside of bags, only a few having crawled in among the grains.

The cadelle, *Tenebroides mauritanicus* L. All specimens of this species of beetle, including a larva, were collected in accumulations of siftings and dust that had lodged in spaces between and beneath the bags of rice. They appeared to be commonly distributed in such material, most of the examples being alive and quite active. Such retreats seemed to be exclusively chosen by the insect for breeding as well as for concealment, since no stage of it occurred in the bagged grain. Yet, in explanation of the presence of three dead larvæ found later in a sample of the same grain, these individuals were believed to have developed in a mixture of siftings which had finally been resacked and replaced in the stacks.

The Angoumois grain moth, *Sitotroga cerealella* Oliv. Moths of this species frequently fluttered and flew away from bags when they were shifted for inspection. These active adults afforded evidence that cold weather had not entirely prevented the breeding of the pest.

The rice weevil, *Calandra oryza* L. The few mature weevils of this species were nearly all found alive, but rather stupid. Only one example, which was much undersized, could be detected on the outer side of the pile of bagged rice. All others occurred among the grains.

The flat grain beetle, *Læmophlœus minutus* Oliv. Adult beetles of this species were scarce, but most of them proved to be alive and active, being found only among the grains.

The short-horned flour beetle, *Latheticus oryzæ* Waterh. This species was not detected at first, but both adult and larval stages were found later by careful examinations of the collected sample of grains. While it exceeded in number that of every other species excepting *Rhizopertha dominica*, yet not as many live stages were detected as in the case of *Læmophlœus minutus*.

The Siamese grain beetle, *Lophocateres pusillus* Klug. Although

very few beetles of this species could be found by later examinations of the sample of grains, the live ones outnumbered the dead.

The book louse, *Troctes divinatoria* Fab. Active specimens considered to be this species were occasionally seen in the powder and dust among the grains.

Eudiagogus rosenschœldi Fah. One dead weevil representing this native species was collected on a bag of rice, and two additional specimens, also dead, were found among the grains. The insect was thought to have been an adventitious introduction from the field, having probably been carried into the grain through the thresher at harvest time. It is not regarded as a foe of rice in any manner.

These statements give an idea of the conditions in which the pests as mentioned specifically pass the winter in stored rice. Reference will be made to these remarks in treating of hibernation.

STATUS OF INFESTATION.

In an effort to determine the status of infestation by the insects occurring in the collected sample of rough Honduras rice, careful search was made for specimens by sorting over the material and picking out all visible live and dead stages of the pests that could be properly identified. The weight of the sample of rice came to exactly three pounds. The results of the examination together with the outcome of a supplementary one, are given in the following tables, the scores being arranged according to the relative importance of the species as was ascertained by the number of stages representing each kind. While the mortality of the stages ran very high, this phase must be regarded as an accumulative result of infestation extending over a period of several months.

Results of first examination, made on March 15 and 16, 1912:

Name of species.	Stage.	No. alive.	No. dead.	Total No.
Rhizopertha dominica	Adult	90	885	975
Latheticus oryzæ	Adult	5	50	55
Sitotroga cerealella	Adult	8	5	13
	Pupa	0	1	1
Calandra oryza	Adult	0	12	12
Læmophlœus minutus	Adult	4	1	5
Lophocateres pusillus	Adult	1	0	1
Grand totals	.....	108	954	1,062

ADDITIONAL.

Troctes divinatoria. Few specimens were found alive in dust, but a reckoning of these was not deemed worth while.

Tenebroides mauritanicus. Specimens taken at time of collection were not included in the count, since they had been picked from between and beneath the bags of the stock. Yet they constituted a small percentage of the general infestation. Larvæ found in second examination, however, were sufficient for a proportionate calculation.

Result of second examination, made on June 12, 1912:

Name of species.	Stage.	No. alive.	No. dead.	Total No.
Rhizopertha dominica	Adult	17	694	711
Lophocateres pusillus	Adult	20	5	25
Sitotroga cerealella	Adult	0	19	19
	Larva	1	0	1
Tribolium navale	Adult	0	10	10
Latheticus oryzæ	Adult	4	3	7
	Larva	3	0	3
Calandra oryza	Adult	1	6	7
Tenebroides mauritanicus	Larva	0	3	3
Læmophlœus minutus	Adult	1	1	2
Grand totals	.....	47	741	788

Additional: *Troctes divinatoria,* numerous.

A summary of the results of the two examinations, including percentages of the proportionate number of live, dead and total stages found according to species, is presented in the following tabulation:

Name of species.	Stages alive.	Stages dead.	Total.
Rhizopertha dominica	107=5.78+%	1,579=85.35+%	1,686=91.14—%
Latheticus oryzæ	12=0.65—%	53= 2.86+%	65= 3.51+%
Sitotroga cerealella	9=0.48+%	25= 1.35+%	34= 1.83+%
Lophocateres pusillus	21=1.14—%	5= 0.28—%	26= 1.41—%
Calandra oryza	1=0.05+%	18= 0.97+%	19= 1.03—%
Tribolium navale	0=0.00%	10= 0.54+%	10= 0.54+%
Læmophlœus minutus	5=0.28—%	2= 0.11—%	7= 0.38—%
Tenebroides mauritanicus	0=0.00%	3= 0.16+%	3= 0.16+%
Grand totals	155=8.38%	1,695=91.62%	1,850=100.00%

The whole number of 1,850 visible stages of the more important infesting insects actually counted in three pounds of rough rice grains gives a quota of approximately 617 stages of the pests per pound. Applying this computation to the stock in storage, every 100 pounds of the grains at the time of the second examination of the sample would be very apt to contain not less than 61,700 living and dead insects, all likely occurring in the adult stage alone. Consideration of eggs, larvæ and pupæ would consequently be in addition. By calculation, however, only 8.38 per cent of the stages were found alive. The proportion of dead ones therefore came to 91.62 per cent.

While these figures afford a basis for comprehending the degree of infestation, they fall far short of a true estimate because of the impossibility of detecting and accounting stages concealed within the grains. Then the probable escape of many individuals from the stock before the sample was obtained, together with other obliterative effects, leaves the question of what would be the full extent of occurrences of the pests in a given time entirely open to speculation.

Since the stock was said to have been grown during the season of 1910, its age from the time of harvesting to June, 1912, covered at least twenty months. The aggregate of the above counts evidently represents a large rather than a small proportion of the entire number of individual pests that had accumulated from infestation extending over this period. The great quantity of dead insects was doubtless due to the dying off of generations, particularly during and after the last winter. Most of the dead adults found by the second examination may reasonably be regarded as having been over-wintered specimens, and the live examples were judged to be representatives of a new seasonal generation. These deductions, of course, must be supported by definite particulars concerning the term of life and behavior of the different species involved. Such data will be presented in accounts of the life history of each species that was studied.

THE ANGOUMOIS GRAIN MOTH.

(*Sitotroga cerealella* Oliv.)

REMARKS ON OCCURRENCES.

According to the status derived by examinations of rough Honduras rice obtained in a general warehouse at New Orleans, La., January 17, 1912, only thirty-four individuals representing the Angoumois grain moth were found in the sample of grains weighing three pounds. On

this basis, the species ranked third in order of importance among the different pests that infested the stock. Previous remarks concerning conditions with regard to this insect at the time of the collection of the infested material need not be repeated here.

Development of stages in the sample evidently progressed without interruption until June 12, the date of the second examination. This course was indicated by the issuance of moths which came out into the light under the glass tumbler on the cover of the jar containing the grains. Although no specimen appeared later than May 9, further evidence of breeding was afforded by the finding of a nearly grown larva during the examination made on June 12. This larva was found wandering freely among the grains, but on being isolated with similar rice, it died within eight days thereafter.

As one or two moths at a time had emerged in February and March, these circumstances gave indication of a continuous breeding of the species throughout the winter and cold weather of spring. However, since the adults, like most other forms of insects that attack stored products, naturally shun bright light, and consequently are not apt to expose themselves in full number to open view, the observations relative to the issue of the specimens from the sample grains have little value towards denoting how much breeding had been carried on by the pest. Then, judging by the spasmodic appearance of the moths at frequent intervals, an overlapping of broods or generations seemed to have occurred and hopelessly confused these phases of existence. On this account, no determinable record could be made respecting the time required for the completion of a life cycle. All the particulars of the life history necessarily remained to be worked out by isolated breeding tests.

OVIPOSITION.

Attempts to breed the species in isolation were begun on March 16, 1912, when five live moths taken during the examination of the sample of infested stock on this date were confined in a tube with sterilized rough rice grains. Owing to a delay in making observations, however, neither the resulting deposition nor hatching of the eggs was known to be effected until April 6, and then the empty egg-shells furnished the only evidence of an issue of larvæ. These shells presented a flattened oval form and still retained a pinkish tint. They were attached in irregular positions on the broad side of the grains, most of them having been placed singly or apart from one another on the surface of the hull, although some were found arranged in a small bunch or else in a short row, with their edges overlapping slightly. In a few cases, as many as five or six shells appeared on a grain, but generally the number per grain ranged from one to three examples.

DEVELOPMENT AND BEHAVIOR OF THE LARVA.

No visible signs of infesting larvæ, except for the presence of the empty egg-shells, could be detected on any of the grains when they were first inspected. Believing, however, that larvæ had issued from the eggs as was indicated by the shells, and then had penetrated in some manner through the hull of separate grains, thus crawling out of sight

on reaching the kernel, examinations of the rice were frequently made at later intervals in efforts to obtain proof of any development of the larval stage. The emergence of a moth on May 9 afforded the first positive evidence of active infestation. Furthermore, the detection of a pupa in each of three other grains was noted on the 15th, 17th and 21st of the same month.

A disposition on the part of the larvæ to wander away for a short distance from their hatching place seemed to be denoted by the emergence of two moths from rough grains that had been kept in different tubes than the one in which the eggs had been deposited. The origin of these moths could be explained only by the probability that newly-hatched larvæ had escaped through the fine gauze covering the vent in the cork of the tube in which they should have remained, and then they had likely crawled to other tubes within their reach, thereby effecting entrance through the same kind of gauze into the interior of the latter. No other way could be conceived that would account for the unexpected cases of introduction in such surroundings. As an extremely minute size of the young larvæ is implied by the circumstances, the ability of the caterpillars to crawl through meshes of coarse bagging cannot be questioned.

The inference drawn from these particular occurrences adds strength to an assumption previously formed that the larvæ at the time when they issue from eggs are capable of engaging in a dispersive movement before they attack grains. This belief is further supported by a contemplation of the probable procedure of the adults in effecting oviposition only between the meshes of sacks filled with rice or else at no considerable depth within the contents, owing to the evident hindrances against obtaining ingress. The point is urged that the occurrence of infested grains within the interior of bags likely becomes due to a dispersal of larvæ in variable courses of more or less length, extending from a prior deposition of eggs which would naturally be expected to have been attached somewhere on the exterior where places of convenient accessibility are offered to the laying parent. Such premises seem to be more consistent than to suppose that a gravid moth could have oviposited on the particular grains at much of a distance inside.

The sign which drew attention to the pupal stage, as will be mentioned later, appeared as a small blotch on the surface of the infested grain. On inserting the point of a pin into the blotch that was first observed, the surface readily parted, and the breach disclosed a pupa occupying a cavity within the kernel. The blotch in this case had been produced on the broad side of the face midway on the grain, but in the subsequent instances, its position was close to the edge or else near an end. While being moderately perceptible to the naked eye in all cases, the discolored surface was found to be extremely thin and slightly puffed outwards when viewed under a magnifier, but yet it always seemed to be intact at this state of advancement.

These observations led to the conclusion that the larva when full grown and about ready to pupate gnaws a place out from its cavity to

reach the surface of the hull, but still leaves a thin epidermal film uncut on the outer face. This action appears necessary to enable the insect to free itself when it matures as a moth, since the adult, not being provided with mouth-parts for gnawing, so far as known, would otherwise be utterly imprisoned in its birthplace and perish there. It is able, however, to break the film, probably by exerting pressure against it, for effecting emergence. The blotch which consequently marks the position of the hollow on the inner side of the hull is the first clue to any injury having been done to the grain. Up to this juncture, the larva seemed to have fed close to the hull, thus forming a shallow channel instead of a perfect burrow in the kernel. In all of such cases, the larva finally pupated within the cavity that it had eaten out during the time of its occupancy.

The matter of working out the particulars of the development of an insect when much of its life is spent in concealment within a product requires special aptitude and patience. Such attendant conditions have to be met in the study of most grain pests inclusive of the present species. Success in prosecuting the work depends on the availability of an ample supply of infested material that will permit losses of stages occasioned by the frequent removal of specimens for examination and still leave a sufficient number for the perfection of observations on the course of life from start to finish.

Owing to the lack of exact data on the deposition and hatching of eggs, nothing more than tentative calculations could be made on the time required for growth of the larvæ. The intervals from date of confinement of the parents until each of the three pupæ was detected, less ten days allowed for the issue of larvæ to take place at the start, cover respectively fifty, fifty-two and fifty-five days for the growth of the larval stage in each instance. With an average larval term of slightly more than fifty-two days, the medial date of pupation fell on May 17. Since the estimates are fully cited in the remarks and schedule given under the concluding topic entitled, "Attainment of a Generation," reference to them should afford a more comprehensive understanding of the reckonings and save their repetition here.

PUPATION.

In the preceding discourse treating of the larval stage, some of the features of pupation have necessarily been mentioned. Further attention, however, is called to the schedule included in the final part of this paper under the heading of "Attainment of a Generation," in which th pupal periods of three additional examples are reckoned. Although the records are insufficient for making a positive calculation of the time required for the development of each pupa, of which the durations were not exactly determined, yet the data will serve to establish a tentative estimate. As near as could be reasonably computed, the pupal period in no instance was less than nine days nor more than twelve days. According to the deductions so obtained, the average time came to nearly eleven days.

Besides the statements already made concerning the pupal stage, but few remarks remain to be given on the subject. Some interest is af-

forded by the position of the pupa with reference to facility in effecting emergence when the insect matures. The head of the pupa that was viewed in its position within the cavity of the kernel rested directly inside of the space marked by the blotch on the hull. Each pupal case observed after the emergence of the adult occupied an exactly similar position with respect to the aperture at this spot through which egress of the moth had been effected. No webs or cocoon inclosed the pupal case. The live pupa was able to twitch vigorously on being pressed or jarred. But one individual has been known to occupy a single grain.

LIFE OF THE ADULT.

The precautionary measure provided by the larva, that allows the adult to emerge through the hull of a grain in which the insect matures, has already been described. As it produces a blotch on the surface, the place is not difficult to detect. After the inmate has liberated itself, the epidermal film, which at first had been left covering the space that the larva had gnawed out on the inner side of the hull, always appeared to be broken outwards by pressure of the moth in effecting its release. The result of the efforts to gain freedom is a circular opening large enough for the insect to pass through and escape. The cap of the opening may be entirely removed or else left hanging by a portion of its edge. In the latter case, it sometimes springs back into place, following the disengagement of the moth.

Should the film which a moth attempts to break be tightly pressed by the face of another grain in a quantity of stock, the possibility of the insect being prevented from forcing an aperture must be considered. In such an event, the adult would surely perish in its birthplace. Considering this contingency, as well as the probable hindrances in other ways which may restrain a moth in undertaking to extricate itself from a mass of grains, in case emergence has taken place at much depth, presents the prospect of the species being more or less subject to mechanical control due to these conditions.

Mating of the sexes is believed to occur after individuals meet in the open air, and the females probably oviposit in the most accessible places on the surface of bagged stock. While the moths may be able to crawl among rough rice, which does not pack as closely as the milled product, yet owing to the obstructive positions of the grains, laying females are not likely to penetrate far beneath the surface for effecting oviposition, even should they readily gain access into a bag. On account of the bagging, for which, however, a coarse texture is used, many adults may fail to find an opening that will allow them to enter a bag. Whether or not gravid moths will deposit their eggs among the fibers of bags in case the grains cannot be reached through the meshes has not been ascertained. At any rate, the depth at which infested grains have been obtained within bags would apparently exclude a moth from ovipositing that far in the interior. In these respects, an explanation should be made that the kind of bag used for handling rough rice is commercially known as a sack, on account of its coarse texture and large size.

Since the moths are commonly found resting on the bags, they are thought to spend most of their lifetime in this manner, although in very dim light, and at nightfall, they hover about on the wing. Reared adults kept in confinement without being allowed to mate at all lived from five or six days to about ten days. On a basis of five records that were obtained in such respects, the data gave an average of eight days for the term of maturity.

ATTAINMENT OF A GENERATION.

According to a published statement, the eggs of the Angoumois grain moth hatch in from four to ten days after deposition. On considering that ten days would afford a sufficient period during moderate weather in early spring to admit of oviposition and the subsequent hatching of the eggs, dating from the confinement of parental moths, which was done on March 16, the resulting issue of larvæ very likely occurred on or about March 26. By using this calculation to fill the gap caused by the lack of timely records, it and the available data on breeding can best be presented in the following schedule. This tabulation is made with reference to the periods of sequential development of stages as were determined in three bleeding tests comprising part of a series. The respective durations are also averaged, and the table concludes with a computation of the number of days required for the attainment of a generation:

Period for deposition and incubation of eggs.	Larval growth.		Pupal term.		Time to maturity.	
	Began.	Days.	Began.	Days.	Began.	Total days.
Dating from confinement of parents on March 16. Estimated at 10 days.	Mar. 26	50	May 15	12	May 27	72
	Mar. 26	52	May 17	11	May 28	73
	Mar. 26	55	May 20	9	May 29	74
Averages	Mar. 26	52	May 17	11	May 28	73
By adding the records of maturity of the three other adults belonging to the same brood, the final calculations will be reduced as follows:					May 9	54
					May 24	69
					May 24	69
Final average for generation					May 24	69

As is shown by the schedule, the time from confinement of parents to the emergence of adults of a new generation ranged from fifty-four to seventy-four days, giving an average of sixty-nine days. On this estimate, as many as five or possibly six generations at least may be expected to occur in a year. Irregularity of development is evident, and summer temperatures may exert an accelerative sway upon the broods. Owing to the incompleteness of records on the breeding of this species, however, much work needs to be done in order to ascertain the particulars of development and seasonal history with exactness and completeness.